

LS-84  
H. Moe  
4-2-87

**Radiological Impacts from  
Operation of  
Argonne Synchrotron  
X-ray Source**

# ARGONNE NATIONAL LABORATORY

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April 2, 1987

TO: E. D. Pentecost EES  
FROM: H. J. Moe SSD/HP  
SUBJECT: Radiological Impacts from Operation of  
Argonne Synchrotron X-ray Source

The recalculation of the offsite doses for the APS utilizing a new set of assumptions has necessitated revision of the doses listed on pages 74 and 75 of the subject document (see Attachment 1). The supporting data for the revised dose estimates is contained in Attachment 2. As indicated in Attachment 2, the same methodology for calculating the direct and skyshine doses, which was used in LS-55, was also used to arrive at the new estimates, which are based on many different assumptions.

In addition, Attachment 3 is a copy of the DOE memorandum which effectively states that the design goal for offsite doses should be less than 25 mrem/y or concurrence from DOE Headquarters is required. It should be mentioned that the DOE is presently revising its radiation protection standards (to be called DOE Order 5480.11), and it is anticipated that the same requirement will be stated in that document.

I hope that the attached information will be of value in the revision of the EA. If there are any questions concerning this material, feel free to contact me on 2-6180.

HJM.11c

Revised Section 4.2.4  
based on 8000 hours of  
operation and new calculations -  
shown in LS-84.  
ATTACHMENT 1

involved with the operation and use of GXS on a continuous basis (Sect. 4.3), and will operate cars in the area from two to four times a day. Car exhaust fumes at GXS will, however, constitute fugitive emissions that will rapidly disperse with insignificant additional environmental effects.

During certain atmospheric conditions, moisture from GXS cooling towers could cause temporary reduction of visibility in nearby (mainly onsite) roads. However, roads near the GXS site are not heavily traveled, and this temporary impact is not expected to result in serious traffic accidents.

Operation of GXS will generate some noise, caused particularly by compressors, cooling towers and site traffic; but, noise levels at 100 m from GXS are not expected to exceed those of neighboring residential areas.

#### 4.2.4 Radiological Impacts

Shielding planned for the facility will ensure that the external penetrating radiation dose to an individual at <sup>220</sup>500 m (<sup>722</sup>1640 ft), the GXS site boundary, will not exceed <sup>~10</sup>~~10-4~~ mrem/yr. This is based on a total yearly operation of <sup>APS</sup> 8000 hr. About <sup>1.6</sup>~~5.5~~ mrem/yr is due to direct radiation and <sup>8.3</sup>~~3.9~~ mrem/yr is due to skyshine (~~AM-1985a~~). The nearest resident (Sect. 3.3.1) is 1.5 km (0.9 mi) west of the <sup>APS</sup> GXS site, and could be expected to receive about <sup>60</sup>~~2.5~~ <sup>μrem/yr.</sup> Individuals in the closest large populated subdivision, 2.1 km (1.3 mi) NW, could be expected to receive about <sup>30</sup>~~0.7~~ <sup>μrem/yr.</sup>

see  
ATTACHMENT  
2  
for  
this data

These doses are conservative estimates in that they do not include reductions due to shielding by residential structures. The applicable Radiation Protection Standards for whole body external radiation dose to the general population is <sup>25</sup>~~500~~ mrem/yr to the maximum exposed individuals (DOE ←

see ATTACHMENT  
3  
for the reference

1984  
 1981). Thus, the expected doses due to <sup>APS</sup>GXS operation would be less than  
<sup>40</sup>~~21~~% of the applicable standard at the site boundary, about <sup>0.24</sup>~~0.50~~% of the  
<sup>0.12</sup>~~0.14~~% of the standard to the nearest resident, and ~~0.14~~% of the standard at the closest  
 large populated subdivision.

It is planned to use Eberline gamma monitors for the entire GXS system. The numbers planned are eight for the Linac, four for the transport line from the Linac to the Synchrotron, 16 for the Synchrotron, four for the transport line from the Synchrotron to the storage ring, and 64 for the Storage Ring (ANL/ORNL 1986b).

It is recommended that two or three additional monitoring stations for external penetrating radiation be located around the GXS boundary, e.g., along Kearney Road and/or the planned GXS Perimeter Road.

Radioactivation of facility air or GXS cooling water is expected to be insignificant or nil.

#### 4.2.5 Ecological Effects

Operation of the proposed GXS will have little potential for impact on ecological resources beyond those occurred during the construction phase. No additional wildlife habitats will be lost unless additions to the facility are constructed. The cooling towers will be relatively small and will not emit sufficient drift to affect vegetation in the area. Effective site restoration and waste water treatment will minimize impacts on water quality (Sect. 4.2.1), thus preventing significant impact on aquatic biota. The small increase in cooling water withdrawal from the Des Plaines River will not have significant entrainment/impingement effects on aquatic biota.

## ATTACHMENT 2

### Dose Estimates for the 1060 m APS Storage Ring

The estimated dose equivalent rates outside the shielded storage ring, and the annual doses to members of the public, have been recalculated using several different assumptions from those which were used in the Conceptual Design Report (ANL-86-8). In addition, an error was made in the previous calculation which resulted in predicted dose rates which were much larger than they should have been.

The methodology used to compute doses in LS-55, which was used by Swanson for the Aladdin Upgrade estimates, was also used for the recalculation. Dose estimates for the case of 1.5 m of concrete shielding, as well as for 0.8 m of concrete shielding for the sides and 1.0 m for the roof, were carried out for the 1060 m circumference ring. A comparison of the two results indicates that 0.8 m of concrete shielding on the side would be sufficient to achieve the desirable dose reduction for the case of occupational exposure. A recalculation of the skyshine contribution, for the case of a larger ring, 1 m of concrete roof shielding and a boundary distance of only 220 m, indicated that the population dose limit of <25 mrem/y would also be met.

#### Direct Radiation

The assumptions used in the recalculation of the direct radiation component were:

Beam Current - 0.3 A  
Circumference - 1060 m  
Positron Energy - 7 GeV  
Beam Mean Lifetime - 10 h  
Shielding - 1 m of concrete on roof, 0.8 m of concrete on the sides  
Total Beam Energy - 7414 J

The results of this calculation for the three radiation components, and their total contribution, are shown in Figure 1, for distances up to 300 m from the positron beam orbit. In addition, values are listed in Table 1 for distances out to 5000 m, and these are plotted in Figure 2, for distances between 100-5000 m. However, in Figure 2, the dose rate H is in terms of mrem/y, based upon an operation time of 8000 h in a year. This data is also shown in Table 1.

### Skyshine Contribution

The contribution to the dose from the scattered neutrons in skyshine was estimated by the same methodology as used in LS-55, but using several different assumptions. These are:

Beam Loss in 10 h -  $0.63 (6.62 \times 10^{12}) = 4.17 \times 10^{12} \text{ e}^+$

Safety Factor - 3, since equation is good only to a factor of 3

Neutron Fluence - 80% fast n of 1 MeV and 20% high energy n

Quality Factor - Used increased Q a factor of 2 higher

Fluence rate to dose equivalent rate conversion factor =  $3.3 \frac{\text{n/cm}^2 \text{ s}}{\text{mrem/h}}$

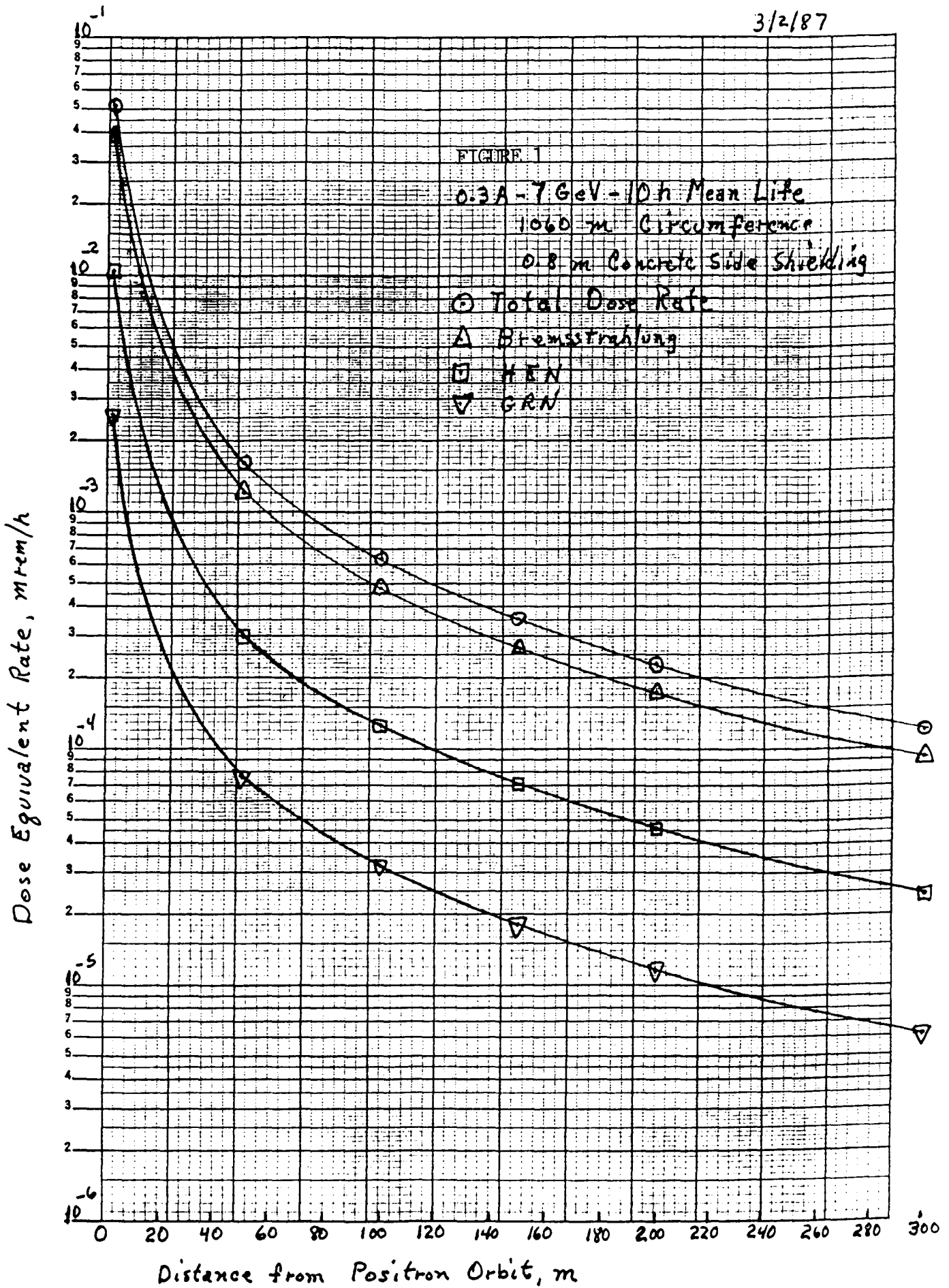
The combination of the above factors leads to this expression for the dose equivalent rate, H:

$$\dot{H} = \frac{9.52 \times 10^5 \text{ e} \cdot \frac{r}{3.3 \times 10^4}}{r^2} \left( \frac{\text{mrem}}{\text{h}} \right),$$

in which r is in cm. The neutron skyshine dose in the region 100-5000 m is plotted in Figure 2, and is larger (or more dominant) than the direct radiation. The data for this plot is also shown in Table 1.

From Figure 1, it is seen that the criterion of  $\leq 0.5 \text{ mrem/h}$  as the ALARA guide for occupational exposure is satisfied at the distance of closest approach (2.0 m). From Figure 2, it is seen that the projected annual dose at 220 m from the positron orbit (at the nearest site boundary) is on the order of 10 mrem/y, also within the guidelines.

3/2/87



# ATTACHMENT 2

TABLE 1

Dose Equivalent Rate - Direct Radiation  
Shielding - 0.8 m of concrete

mrem/h

Distance, m	Bremsstrahlung	High Energy Neutrons	Giant Resonance Neutrons	Total
2.0	$3.884 \times 10^{-2}$	$1.030 \times 10^{-2}$	$2.551 \times 10^{-3}$	$5.169 \times 10^{-2}$
100	$4.750 \times 10^{-4}$	$1.262 \times 10^{-4}$	$3.186 \times 10^{-5}$	$6.331 \times 10^{-4}$
150	$2.669 \times 10^{-4}$	$7.093 \times 10^{-5}$	$1.790 \times 10^{-5}$	$3.557 \times 10^{-4}$
200	$1.733 \times 10^{-4}$	$4.605 \times 10^{-5}$	$1.161 \times 10^{-5}$	$2.310 \times 10^{-4}$
300	$9.126 \times 10^{-5}$	$2.425 \times 10^{-5}$	$6.099 \times 10^{-6}$	$1.216 \times 10^{-4}$
400	$5.664 \times 10^{-5}$	$1.505 \times 10^{-5}$	$3.777 \times 10^{-6}$	$7.547 \times 10^{-5}$
500	$3.866 \times 10^{-5}$	$1.027 \times 10^{-5}$	$2.573 \times 10^{-6}$	$5.151 \times 10^{-5}$
1000	$1.118 \times 10^{-5}$	$1.967 \times 10^{-6}$	$7.399 \times 10^{-7}$	$1.489 \times 10^{-5}$
1500	$5.245 \times 10^{-6}$	$1.392 \times 10^{-6}$	$3.462 \times 10^{-7}$	$6.983 \times 10^{-6}$
2000	$3.036 \times 10^{-6}$	$7.055 \times 10^{-7}$	$2.001 \times 10^{-7}$	$4.042 \times 10^{-6}$
3000	$1.389 \times 10^{-6}$	$3.686 \times 10^{-7}$	$9.144 \times 10^{-8}$	$1.850 \times 10^{-6}$
4000	$7.935 \times 10^{-7}$	$2.105 \times 10^{-7}$	$5.218 \times 10^{-8}$	$1.056 \times 10^{-6}$
5000	$5.125 \times 10^{-7}$	$1.359 \times 10^{-7}$	$3.368 \times 10^{-8}$	$6.822 \times 10^{-7}$

Dose Equivalent Rate - Direct Radiation for 8000 h Operation

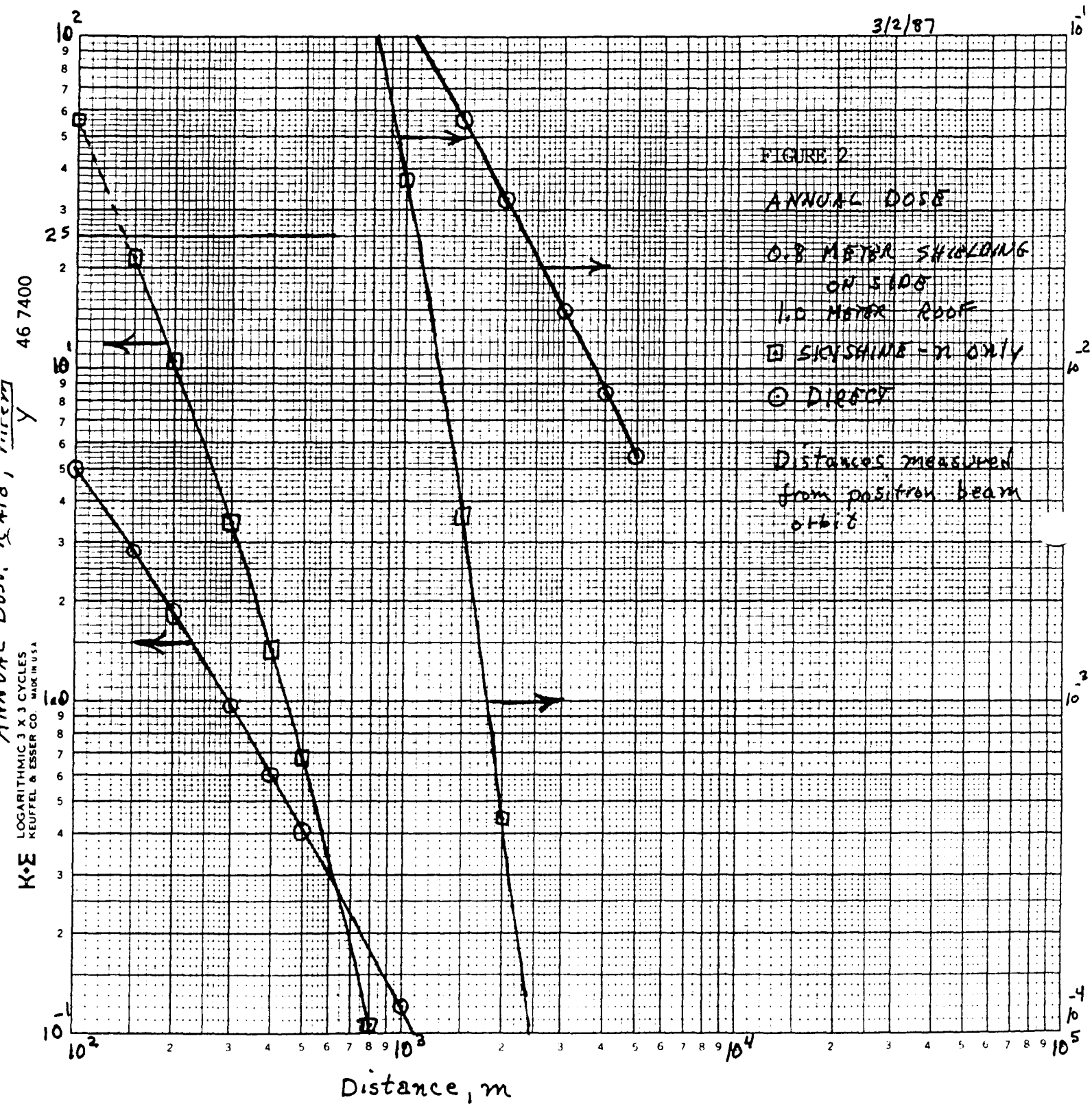
mrem/y

Distance, m	Bremsstrahlung	HEN	GRN	Total
100	3.80	1.01	0.25	5.06
200	1.39	0.37	$9.29 \times 10^{-2}$	1.85
300	0.73	0.19	$4.88 \times 10^{-2}$	0.97
400	0.45	0.12	$3.02 \times 10^{-2}$	0.60
500	0.31	$8.22 \times 10^{-2}$	$2.06 \times 10^{-2}$	0.41
1000	$8.94 \times 10^{-2}$	$2.37 \times 10^{-2}$	$5.92 \times 10^{-3}$	0.12
1500	$4.20 \times 10^{-2}$	$1.11 \times 10^{-2}$	$2.77 \times 10^{-3}$	$5.59 \times 10^{-2}$
2000	$2.43 \times 10^{-2}$	$6.44 \times 10^{-3}$	$1.60 \times 10^{-3}$	$3.23 \times 10^{-2}$
3000	$1.11 \times 10^{-2}$	$2.95 \times 10^{-4}$	$7.32 \times 10^{-4}$	$1.48 \times 10^{-2}$
4000	$6.35 \times 10^{-3}$	$1.68 \times 10^{-3}$	$4.17 \times 10^{-4}$	$8.45 \times 10^{-3}$
5000	$4.10 \times 10^{-3}$	$1.09 \times 10^{-3}$	$2.69 \times 10^{-4}$	$5.46 \times 10^{-3}$

# Neutron Skyshine

mrem/y

Distance, m	$\dot{H}$ ( $\mu\text{rem/h}$ )	$\dot{H}$ (mrem/y)
100	(7.03)	(56.3)
150	2.69	21.5
200	1.30	10.4
300	$4.27 \times 10^{-1}$	3.4
400	$1.77 \times 10^{-1}$	1.4
500	$8.37 \times 10^{-2}$	0.67
1000	$4.60 \times 10^{-3}$	$3.68 \times 10^{-2}$
1500	$4.49 \times 10^{-4}$	$3.59 \times 10^{-3}$
2000	$5.55 \times 10^{-5}$	$4.44 \times 10^{-4}$
3000	$1.19 \times 10^{-6}$	$9.51 \times 10^{-6}$
4000	$3.24 \times 10^{-5}$	$2.59 \times 10^{-7}$
5000	$1.00 \times 10^{-9}$	$8.01 \times 10^{-9}$



Royer

United States Government

Department of Energy

# memorandum

DATE: SEP 17 1984

REPLY TO

ATTN OF: PE-243

SUBJECT: Proposed Revision of DOE Order 5480.1A, Radiation Standards for Protection of the Public

TO: William W. Hoover, DP-1  
Alvin W. Trivelpiece, ER-1  
James W. Vaughan, NE-1  
Managers, DOE Operations Offices

Attached for review and comment is a proposed revision of DOE radiation standards for protecting the public in the vicinity of DOE facilities. Currently, DOE Order 5480.1A (Chapter XI) incorporates radiation standards derived in the 1950's. The proposed revision is intended to bring the DOE radiation standards up-to-date and into conformance with current international guidance on protecting the public.

The International Commission on Radiological Protection (ICRP) system (ICRP publications 26 and 30) was chosen to serve as a basis for this proposed revision because it is the only current authoritative guidance available and, with some adaptations, will meet DOE needs in assuring public protection. The proposed revision will incorporate dose equivalent conversion factors, currently being developed for publication as a DOE technical document. The dose conversion factors are being calculated based on models and parameters in the ICRP publication 30, including the 50-year period for integrating committed effective dose equivalents for radionuclides having long residence times in the human body.

The proposed revision embodies the ICRP recommended range of  $10^{-6}$ - $10^{-5}$  per year risk that "... would be likely to be acceptable to any individual member of the public." The upper limit of this range is nominally equivalent to 100 mrem/year. However, in conformance with the ICRP recommendations, a higher limit of 500 mrem/year is governing for short periods of exposure. An arbitrary time of 5 years was chosen to distinguish between short periods and prolonged periods of exposure.

The proposed revision will also strengthen the DOE procedural requirements for assuring that exposures to members of the public are maintained as low as reasonably achievable (ALARA). The proposed procedures incorporate a provision for Headquarters concurrence for anticipated routine operations that may result in estimated exposures exceeding 25 mrem/year to any member of the public.

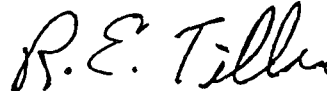
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HEALTH PHYSICS SECTION

SEP 24 1984

It is not proposed at this time to revise DOE radiation standards for the protection of workers. An interagency committee chaired by the EPA is developing Federal guidance on worker protection. Since occupational internal exposures can be controlled on an annual basis, unlike population exposures, the Department has taken the official position that internal exposures will be assessed based on annual dose commitment. It is intended to revise the occupational standard when EPA finalizes the Federal Occupational Standards Guidance.

It is important that we receive comments from your office on the proposed revision at the earliest possible time, and not later than October 5. You may already be aware that EPA is under court order to take final action on its April 6, 1983, proposed Clean Air Act emission standards for radionuclides by October 29, 1984. We believe that EPA will be interested in our efforts to update the DOE standards for protecting the public, therefore, we wish to proceed with the order revision as rapidly as possible.

Comments from your office may be communicated to D. E. Patterson by FAX or TWX, or called in to Carl Welty on FTS 233-5642. Questions concerning the proposed order revision should be addressed to Mr. Welty.



Robert E. Tiller  
Acting Deputy Assistant Secretary  
for Environment, Safety and Health

Attachment

cc: See attached list

# RADIATION STANDARDS FOR PROTECTION OF THE PUBLIC IN THE VICINITY OF DOE FACILITIES

## A. POLICY ON EXPOSURE TO THE PUBLIC

It is the policy of the Department of Energy that:

- o no activity involving radiation shall be undertaken unless its introduction produces, or promises to produce, a positive net benefit to society as a whole;
- o all exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account; and
- o the effective dose equivalent to any member of the public shall not exceed the limits specified in Part B below.

## B. LIMITS FOR MEMBERS OF THE PUBLIC FROM ROUTINE DOE OPERATIONS\*

Annual dose equivalents for members of the public from all routine operations (natural background and medical exposures excepted) shall not exceed the values given below:

	Effective dose equivalent <sup>1</sup> mrem/year (mSv/year)	
Occasional annual exposures <sup>2</sup>	500	(5)
Prolonged period of exposure <sup>2</sup>	100	(1)

No individual organ shall receive a committed dose equivalent of 5 rem/year (50 mSv/year) or greater.

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Effective dose equivalents will be expressed in rem (or millirem) with the corresponding value in sieverts (or millisieverts) in parentheses.

In ICRP-39 it is stated that "For stochastic effects in members of the public the Commission recommends that the committed effective dose equivalent from exposure to radioactive materials in any year be limited to 5 mSv, and, for repeated exposures over prolonged periods, that it would be prudent further to restrict this to 1 mSv from each year of lifelong exposure." For the purposes of this order, a prolonged exposure will be one that lasts, or is predicted to last, longer than 5 years.

\*The effective dose equivalent limits are based on the annual effective dose equivalent received after an assumed exposure period of 50 years (50 year committed effective dose equivalent). Since the population is an uncontrolled group, the dose commitment methodology provides a rational base for control and dose assessment in contrast to such application for occupational worker control and dose assessment. The latter is a controlled group, and the annual dose equivalent methodology provides more effective control and assessment.

### C. "AS LOW AS REASONABLY ACHIEVABLE (ALARA)"

#### 1. General ALARA Requirements

The application of the principle of "as low as reasonably achievable (ALARA)" is site specific and job specific. As a result, no dose limits can be directly applied without specific knowledge of the facility. It is the responsibility of each worker and manager to use their best judgment to assure that emissions and resulting dose equivalents to members of the public are as low as reasonably achievable. Program offices and contractors will, therefore, implement the following policies:

- (a) No individual or group of individuals in the environs of a DOE facility shall be exposed to amounts of radiation that could be reduced by reasonable efforts and use of resources.
- (b) The design of each new facility shall undergo a documented review that demonstrates that all emissions will be expected to meet ALARA requirements. Such reviews shall consider the effectiveness and cost of alternative controls along with the emission reduction and dose equivalent reduction achieved by such controls. The basis for such judgment on control alternatives shall be specifically documented.
- (c) When the emission system is changed or if emissions are increased, a documented review similar to that above shall be completed.
- (d) In addition, a documented facility-by-facility review of the appropriateness of current ALARA practices for the reduction of environmental exposures shall be conducted at least every five years.

#### 2. ALARA Review and Approval

Field Offices shall review and approve ALARA review documents required by C.1 above to assure compliance with DOE ALARA requirements. Managers of field offices shall refer all such documents to PE-1 for concurrence in those instances in which predicted effective dose equivalents to individual members of the public exceed 25 mrem per year from DOE operation or from the combined operations of DOE and other facilities. PE-1 shall consult with appropriate program offices before deciding on concurrence or non-concurrence.

### D. QUANTITIES FOR DETERMINING THE EFFECTIVE DOSE EQUIVALENT

#### 1. The Quality Factor

For the purposes of this Order, the following Quality Factors will be used to calculate dose equivalent values:

X-rays, gamma rays, and electrons	1
Neutrons, protons, and singly-charged particles of rest mass greater than one atomic mass unit	10
Alpha particles and multiply-charged particles	20

## 2. Weighting Factors

The following organ weighting factors shall be used in the calculation of the effective dose equivalent.

Tissue or Organ	Weighting Factor
Gonads	0.25
Breast	0.15
Red Bone Marrow	0.12
Lung	0.12
Thyroid	0.03
Bone Surfaces	0.03
Remainder	0.30

The weighting factor of 0.30 for the remainder is to be divided among five remaining organs with the highest committed dose equivalents<sup>1</sup>. A value of 0.06 shall be used for each of these organs with the dose to all other organs ignored.

## E. IMPLEMENTATION (Dose Assessment)

External dose should be estimated from measurements as closely to the maximally exposed individual as possible. Meteorological dispersion calculations can be used to supplement these measurements, particularly if these models are calibrated for the region.

Internal dose should be estimated from measurements of air, water, and foodstuffs. However, dispersion and pathway analyses should be performed to estimate the effective dose equivalent as a secondary reference, particularly if radioactivity concentrations are below minimum detectable levels.

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<sup>1</sup>In practice, the ICRP uses a 10% rule in evaluating committed dose equivalent. That is, organs which in total provide less than 10% of the total effective dose equivalent are ignored. This often results in less than five organs in the remainder being considered.

In routine situations, the effective dose equivalents, as well as the committed dose equivalent for important organs, shall be estimated using the committed dose equivalent conversion factors (derived from ICRP Publication 30 parameters) provided in \_\_\_\_\_

#### F. ACCIDENTS

The exposure limits given in Part B above are for routine DOE operations and are not intended for use as criteria to evaluate the acceptability of postulated accidental events. Planning for the prevention or mitigation of accidents and their effects shall be accomplished in conformance with DOE Policy as stated in Part A above and in accordance with the requirements of DOE 5480.1A, Chapter V, "Safety of Nuclear Facilities" and Chapter VI, "Safety of Department of Energy Owned Reactors."

Following any accident that causes or threatens to cause exposures to members of the public in excess of the limits given in Part B above, the HQ Program Office and PE-1 shall jointly evaluate the accident and resulting exposures, and advise the Secretary concerning the operational status of the facility or activity that gave rise to the accident and corrective measures.

#### G. DEFINITIONS

##### 1. Committed Dose Equivalent

The dose equivalent received for a period of 50 years resulting from the intake or deposition of a radionuclide in any one year.

##### 2. Dose Equivalent

The product of the absorbed dose to the body or an organ and the Quality Factor.

##### 3. Effective Dose Equivalent

The sum of the dose equivalent received from external sources plus the sum of the committed dose equivalent to each organ, the latter multiplied by the weighting factor (D.2. above) appropriate to each organ.

##### 4. Quality Factor (Q)

A multiplying factor for a dose equivalent to the body or an organ to allow for the additional damage caused by radiations that produce higher ionization densities than x- or gamma radiation. This factor is applicable only for purposes of radiation protection and should not be used for accidental high exposures.

##### 5. Routine DOE Operations

Routine DOE operations mean normal planned operations. Routine operations do not include actual or potential accidental or unplanned releases.